Bus Passenger Walking Distances and Waiting Times: A Summer-Winter Comparison

WILLIAM LAM AND JOHN MORRALL

Mr. Lam has a M.Sc. degree in transportation planning from The University of Calgary. He is currently engaged in new town development projects in Hong Kong with Maunsell Consultants Asia.

Dr. Morrall is a professor in the Department of Civil Engineering at The University of Calgary. Previously, he was employed at the Ontario Ministry of Transportation and Communications and the Metropolitan Toronto and Region Transportation Study. He received his Ph.D. degree in transportation planning from the University of Waterloo.

WITH mean daily temperatures of −17°C in January it is not surprising that climatic conditions such as temperature and wind speed are factors that influence bus passenger walking distances and waiting times in northern cities such as Calgary, Alberta. What is surprising, however, is the lack of information in Canada on not only the effect that inclement weather has on transit access but the entire spectrum of urban transportation planning and operations criteria including such critical elements as roadway capacity. The objectives of this study were to:[1]

1. measure walking distances to and waiting times at bus stops during summer and winter conditions.
2. perform appropriate statistical analyses of the data collected; and
3. develop refined measures for urban planning purposes including the primary catchment area of a bus stop, detour factors, and to determine the effect of inclement weather on bus passenger walking and waiting times.

While the data was confined to one city, the general findings should be applicable to other North American cities of similar size and character. In order to facilitate the transferability of the findings, a

1. "Walking and Waiting Time Study for Bus Transit Systems," Department of Civil Engineering, The University of Calgary, 1980.

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brief profile of the city, the transit system, and meteorological data are included.

STUDY AREA

Calgary, Alberta, the study area, is a city of 553,000 population (1980) and an area of 488 square kilometers (188 square miles) located at a latitude of 51 degrees and an altitude of 1,050 metres (3,445 feet). The city has been growing at the rate of approximately 1,500 persons per month over the past decade. While the city may be characterized as being typical of western North American cities, namely, low density, high auto ownership, and residential neighborhoods dominated by single family dwellings, it differs from many in that it has a well-defined, strong, intensively developed downtown. With approximately 71,000 downtown employees concentrated in an area of 240 hectares (593 acres) and parking in scarce supply and expensive, the peak hour CBD oriented modal split exceeds 40 percent. Total transit rides per capita on a city-wide basis are slightly in excess of 100, while the system carried approximately 90 revenue passengers per capita. The city owned transit system, Calgary Transit, serves approximately 90 percent of the developed portion of the city with 574 buses on 77 routes. The CBD is served with both express and local buses using city streets, bus only lanes and a 13-kilometer (8-mile) light rail system.

The northern location and high altitude of the city result in a wide variation in extreme temperatures. A summary of meteorological observations over an 86-year period are shown in Table I.

Transit passengers are well aware of how much colder it feels outdoors on a windy day as compared to when there is no wind, particularly in winter. The wind chill factor is a measure of the combined effect of wind and temperature. For example, an air

TABLE I—SUMMARY OF METEOROLOGICAL OBSERVATIONS AT CALGARY, ALBERTA OVER A PERIOD OF 86 YEARS[a]

	Temperature in Degree Celsius (°C)		
	January	*July*	*Year*
Mean Daily Maximum	−5.3	23.5	9.7
Mean Daily Minimum	−16.7	9.5	−2.9
Mean Daily	−10.9	16.5	3.4
Extreme Maximum	16.1	36.1	36.1
Extreme Minimum	−44.4	−0.6	−45.0

[a]The City of Calgary, *Municipal Handbook of Interesting Information and Authoritative Statistics*, November 1977.

temperature of −15°C and wind speed of 24 km/h (15 mph) represent the condition where exposed flesh will freeze (a wind chill factor of 1,625 watts per square metre).

DATA COLLECTION

Selection criteria to determine bus stops to be used for data collection included such factors as, residential density, spacing and location of bus stops, passenger volumes, route type, and headway. Transfer points were excluded to avoid confusion between transfer passengers and passengers arriving on foot. Using this criteria, two to five stops were selected in each of five residential areas throughout the city. In addition, a university, a downtown, two industrial sites and three suburban shopping centers were also surveyed. The presence of a shelter was not a factor in selecting a particular stop as the sites meeting all criteria had shelters. In fact, practically all routes now have shelters on the inbound direction, at all stops with major volumes, and at transfer points. In total over 2,400 observations were taken at the 40 bus stops selected for data collection. As a sample size guideline it was considered desirable to estimate both the average walking and waiting times so that there would be a 95 percent probability of having an error of no more than 30 seconds. For larger headways of 30 to 60 minutes, an error within 1 or 2 minutes was considered acceptable. In general, most of the bus stops selected were on regular local routes and downtown express bus routes. Residential neighborhood bus stops were surveyed between 6:30 and 8:30 AM, the downtown and industrial areas between 3:00 and 5:30 PM, and the university and shopping centers between 9:00 AM and 9:00 PM.

Measurement of Walking Distances

A review of transit passenger walking distance surveys conducted in other cities suggests that for the degree of accuracy required at the pedestrian scale, conventional origin-destination surveys of the home interview or telephone variety are simply not accurate enough. In the Calgary study walking distance data was collected by stationing surveyors at the selected bus stops to interview bus passengers. Bus passengers were asked to indicate the exact origin of their walking trip and to trace their path between origin and bus stop on a 1 to 400 legal base map. The surveyors provided assistance in map reading and direction orientation as some bus passengers had a sense of neither. In addition, bus passengers were asked questions regarding their trip

purpose and whether or not a car was available for the trip. Upon completion of a survey at each stop, the walking path traced on the base map was scaled and entered along with other information including wait time, trip maker and trip purpose characteristics, land-use information, bus route data, and meteorological data, on a computer based file.

Measurement of Waiting Times

Waiting times were measured using easily-read illuminated watches. Passenger arrival times, and the arrival times and departure times of buses were recorded. Depending on passenger volume at each stop, between two and three surveyors were required to obtain data. This information was entered on a computer file along with all other pertinent information such as scheduled arrival and departure times.

Measurement of Walking Speeds

Measurement of walking speeds to bus stops were taken for summer and winter conditions. Observations were clustered about an average walking speed of 80 meters/minute (262 fpm) similar to that reported in other studies.[2] Field observations showed that walking speeds are slightly faster in winter even though sidewalks and streets may be slippery with ice and snow. In addition, it was observed that walking speeds varied over the length of the journey to the bus stop. For example, bus passengers would walk slightly faster until the bus stop was in view, then reduce their pace. A waiting or approaching bus typically resulted in the fastest walking access times. The average walking speed of 80 meters/minute (262 fpm) was used to convert walking distance to walking time, which in turn was added to waiting time in order to determine total access time.

Meteorological Data

Data was collected during the summer of 1979 and winter of 1980. These two particular periods were considered to be representative of average summer and winter conditions in Calgary. A summary of meteorological observations taken during the course of the field surveys is shown in Table II. Wind speed is of interest because when combined with low temperatures the resulting wind chill factor is much lower than temperature alone. Summer observations were taken in May, June, July, and August 1979, while winter observations were taken in January and February of 1980.

2. John J. Fruin, *Pedestrian Planning and Design,* Metropolitan Association of Urban Designers and Environmental Planners, New York, 1971.

TABLE II—SUMMARY OF METEOROLOGICAL OBSERVATIONS DURING THE SUMMER AND WINTER SURVEYS

	Summer			*Winter*		
	AM Peak	*Off-peak*	*Daily*	*AM Peak*	*Off-peak*	*Daily*
Mean Temperature °C	8.1	21.8	18.4	−23.1	−17.4	−19.6
Mean Wind Speed km/h	3.7	4.5	4.2	12.6	5.9	8.6
(mph)	(2.3)	(2.8)	(2.6)	(7.8)	(3.7)	(5.3)

WALKING DISTANCE DISTRIBUTIONS

Mean walking distances for selected areas are shown in Table III. Mean walking distances in selected suburban residential areas (primarily single family dwelling) during the AM peak period for headways in the 5 to 8 minute range were found to be 373 and 348 meters (1,224 and 1,142 feet) for summer and winter respectively. Mean walking distances to express and regular route service in the central business district for 5 to 8 minute headways were found to be 273 and 354 meters (896 and 1,161 feet) summer and winter respectively. Mean walking distances from the same stops in the central business district were found to be 311 and 356 meters (1,020 and 1,168 feet) for summer and winter respectively. The Calgary central business district is basically a one-way street system. During the course of the study there were several route changes due to light rail transit construction, street construction, and downtown building construction. Thus, walking distance distributions in the central business district are constantly changing and probably will not stabilize until downtown development is complete, which may be several decades. Mean walking distances to bus stops in industrial areas were found to be 170 and 208 meters (558

TABLE III—MEAN WALKING DISTANCES IN SELECTED AREAS

Service Area	*Route Type*	*Headways (seconds)*	*Mean Walking Distance meters (feet)*	
			Summer	*Winter*
Suburban Residential	Express & Regular	300–480	373 (1,224)	348 (1,142)
Central Business District	Access to Express & Regular	300–480	273 (896)	354 (1,161)
Central Business District	Egress from Express & Regular	300–480	311 (1,020)	356 (1,168)
Industrial Area	Access to Industrial Feeder	1,800	170 (558)	208 (682)
Industrial Area	Egress from Industrial Feeder	1,800	175 (574)	214 (702)

and 682 feet) for summer and winter respectively. Mean walking distances from bus stops in industrial areas were found to be 175 and 214 meters (574 and 702 feet) for summer and winter respectively. With the exception of the suburban residential areas, mean walking distances for winter are greater than summer. This can be partly explained by the fact that the detour factor for winter is greater than summer. However, it is difficult to generalize from these results for selected areas owing to the wide range of factors that come into play, including more post-secondary and institutional trips in winter than summer, summer vacations that result in up to 20–25 percent of the work force on vacation at one time, and more reliance on transit in winter, especially during very cold periods when autos refuse to start or streets are dangerous due to snow and ice.

Walking distance distributions to bus stops for summer, winter, and overall are depicted in Figure 1. The median, and mean walking distances are summarized in Table IV. As shown in Figure 1, the 75th percentile is approximately 450 meters (1,476 feet), the distance the City of Calgary Transportation Department has identified as being

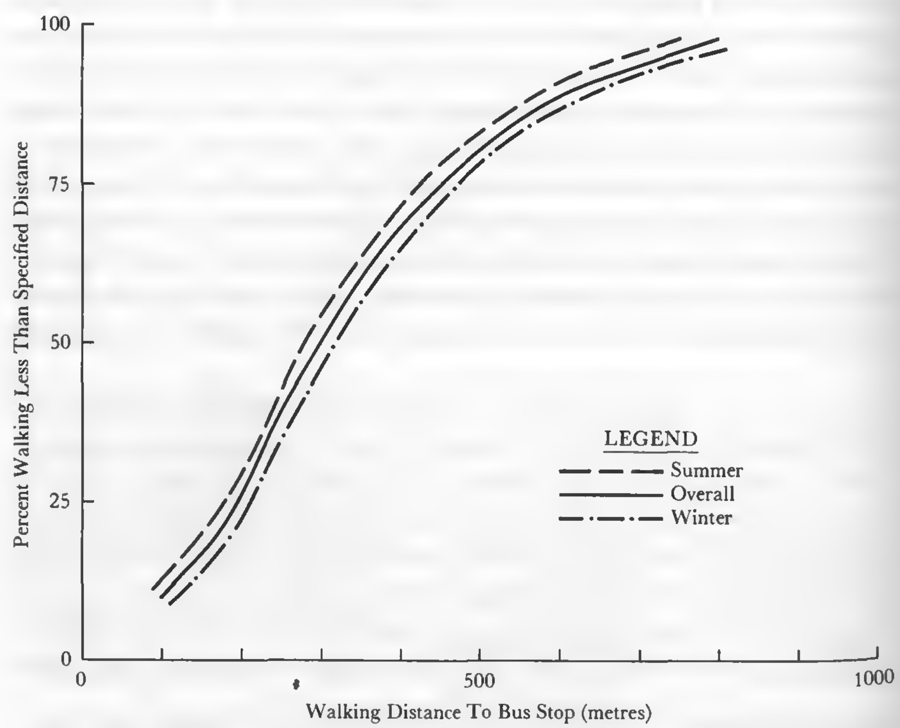


Figure 1. Walking distance to bus stop in Calgary

TABLE IV—BUS PASSENGER WALKING DISTANCES

	Summer	*Winter*	*Overall*
Mean Distance meters	322	329	327
(feet)	(1,056)	(1,079)	(1,073)
Median Distance meters	281	312	292
(feet)	(922)	(1,024)	(958)

the primary catchment area. Table IV indicates that on an overall basis the mean walking distance for winter is slightly longer than that for summer.

A comparison of the overall walking distance distribution obtained for Calgary is made with Edmonton and Vancouver in Figure 2. The comparison indicates that bus passengers in Calgary are prepared to walk further than residents of Edmonton or Vancouver. However, it is cautioned that comparisons must be made bearing in mind that the distributions for each city were obtained by different survey methods. The survey conducted in Calgary was the only one in which bus passengers were asked by surveyors to trace their walking path on a base map, thus obtaining the exact distance walked.

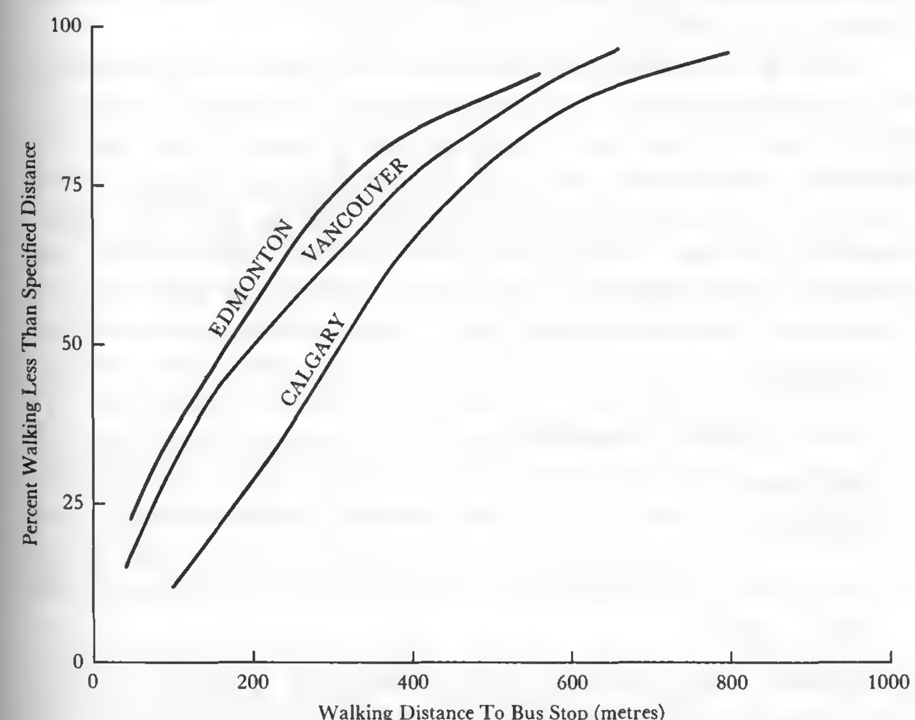


Figure 2. Walking distance to bus stops in Canadian cities
Source: Adapted from the Canadian Transit Handbook

TABLE V—MEAN WAITING TIMES IN SELECTED AREAS

Service Area	Route Type	Headways (seconds)	Mean Waiting Times (seconds) Summer	Winter
Suburban Residential	Express & Regular	300–480	187	159
Central Business District	Express & Regular	300–480	162	125
Industrial Area	Industrial Feeder	1,800	417	394
University Campus	Local & Cross-Town	600	297	227
		720	344	323
		900	370	354
		1,800	696	558
		3,600	748	626
Shopping Centers	Local, Express & Cross-Town	720	389	419
		900	403	446
		1,800	591	468

WAITING TIME DISTRIBUTIONS

Mean waiting times for selected areas are shown in Table V. The hypothesis that average waiting times in summer are greater than that in winter is supported by this study. There is a tendency for passengers, especially during inclement weather, to arrive at bus stops just before the expected arrival time of the bus.

Waiting time distributions for summer, winter, and overall as a function of bus headway are shown in Figure 3. As shown in Figure 3, the average waiting time is approximately equal to one-half the headway, for headways under 600 seconds. Beyond this point the use of this approximation overstates average waiting time. For longer headways average waiting time tends to be approximately 660 seconds. The relationship between average waiting time and bus headway has been determined to be:

Summer

$$w = -1188 + 236 \ln(\text{obs}) \quad (1)$$

$(R^2 = 0.81)$

Winter

$$w = -948 + 193 \ln(\text{obs}) \quad (2)$$

$(R^2 = 0.79)$

Overall

$$w = 1067 + 215 \ln(\text{obs}) \quad (3)$$

$(R^2 = 0.82)$

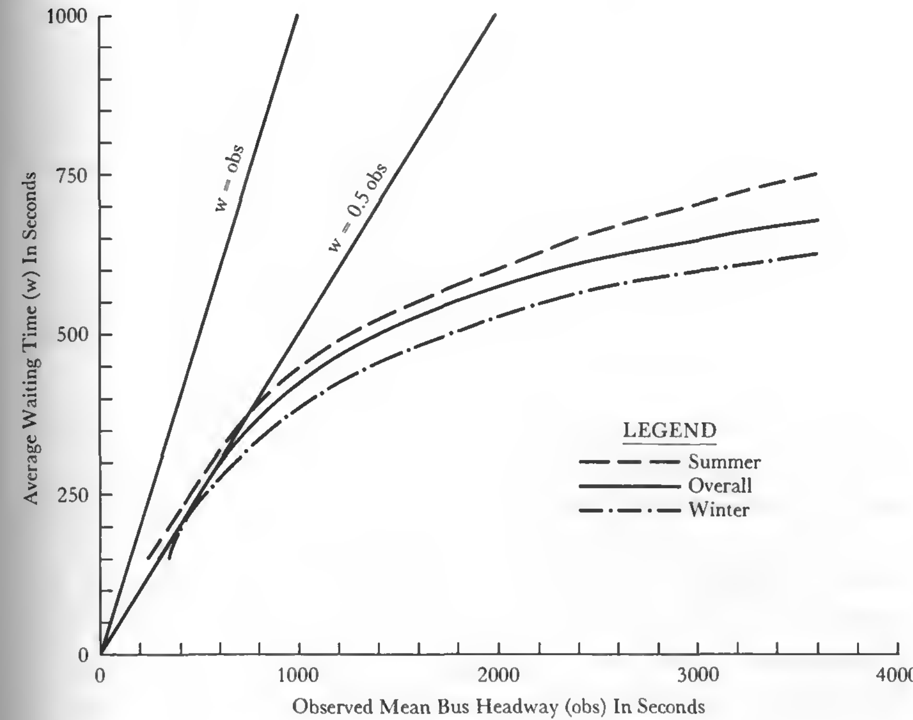


Figure 3. Average waiting time versus observed mean bus headway

where

w = average waiting time in seconds

obs = observed bus mean headway in seconds

To test the hypothesis that arrivals are random, the test methods used by Smith *et al* and Seddon and Day were followed.[3] Basically the tests involved dividing each headway into four and eight equal parts. The second step involved determining passenger arrivals in each interval. Thus, if the arrival of passengers was completely random, the total number of passengers arriving in each interval would be the same. The actual and predicted number of arrivals in each interval was compared using the chi-square test in order to test the random arrival hypothesis. The tests showed that there was no discernible

3. B. T. Smith, R. M. Solard, and J. C. Warmoes, "Collection and Analysis of Data on Public Transit: Section 2: Arrival Patterns of the Users". A working paper prepared for the Urban Transportation Research Branch of Canadian Surface Transportation Administration, Transport Canada, December 1978. P. A. Seddon and M. P. Day, "Bus Passenger Waiting Times in Greater Manchester", *Traffic Engineering and Control,* Vol. 15, 1974, pp. 442–445.

TABLE VI—TOTAL ACCESS TIMES FOR SELECTED AREAS

			Mean Total Access Times (seconds)					
			Summer			*Winter*		
Service Area	*Route Type*	*Headways (seconds)*	*Walk*	*Wait*	*Total*	*Walk*	*Wait*	*Total*
Suburban Residential	Express & Regular	300–480	278 (60%)	187 (40%)	465 (100%)	260 (62%)	159 (38%)	419 (100%)
Central Business District	Express & Regular	300–480	203 (56%)	162 (44%)	365 (100%)	265 (68%)	125 (32%)	390 (100%)
Industrial Area	Industrial Feeder	1,800	127 (23%)	417 (77%)	544 (100%)	155 (28%)	394 (72%)	549 (100%)
			Generalized Total Access Component Percentages					
City-Wide	All Route Types	All Headways	55%	45%	100%	65%	35%	100%

dependence of the chi-square value on average headway, theoretical average waiting time or average waiting time. These findings are in general agreement with those reported by Smith *et al* for Montreal and O'Flaherty and Mangan for Central Leeds.[4] The findings can be partly explained by the field observations noted earlier of bus passengers increasing their walking speed to catch an approaching or waiting bus. In other words, there is a tendency for bus passengers to arrive at stops toward the end of the headway.

TOTAL ACCESS TIME

Total access time was determined by converting walking distance to walking time using an average walking speed of 80 meters/minute (262 fpm) and adding this value to the corresponding waiting time:

$$\text{total access time} = \text{walking distance}/(80 \text{ meters/minute}) + \text{wait time} \tag{4}$$

Table VI shows the total access time to bus stops for selected areas. In the selected suburban residential areas the walk and wait access components were 60 percent and 40 percent for both summer and winter, although total access time was found to be longer for summer than winter. In the selected industrial areas total access time was similar for summer and winter, however the walk and wait components were roughly 25 and 75 percent respectively. Also shown in the same table are the walk and wait components on a city-wide basis. In general, bus passengers have access component ratios of 55 percent walk and 45 percent wait in summer, and 65 percent walk and 35 percent wait in winter, although these ratios vary from area to area and within areas.

4. C. A. O'Flaherty and D. O. Mangan, "Bus Passenger Waiting Times in Central Areas", *Traffic Engineering and Control*, Vol. II, 1970, pp. 419–421.

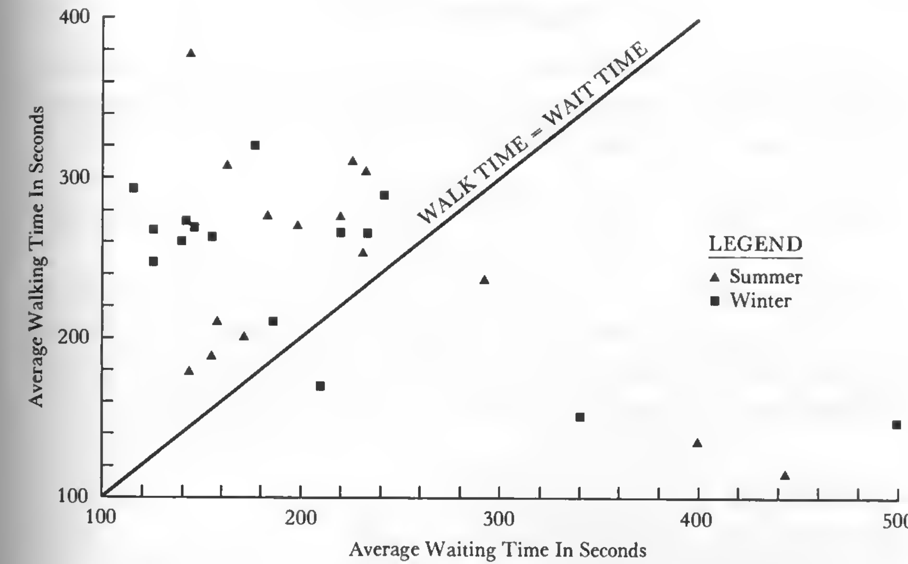


Figure 4. Average walking time versus average waiting time

Figure 4 shows average walking time versus average waiting time for summer and winter conditions, while Figure 5 displays the same data but as a percent of total access time. In most cases, summer and winter, the average wait is less than the average walking time, the only exceptions being the industrial areas surveyed.

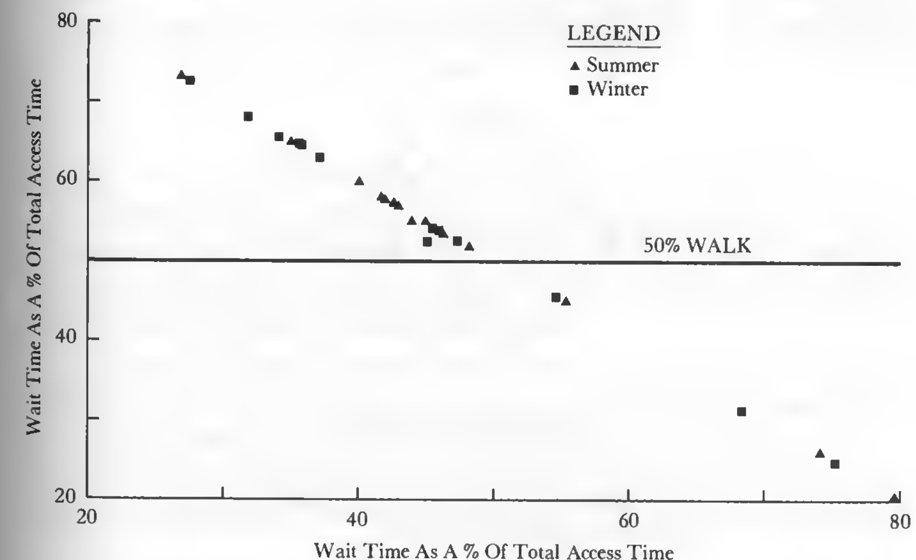


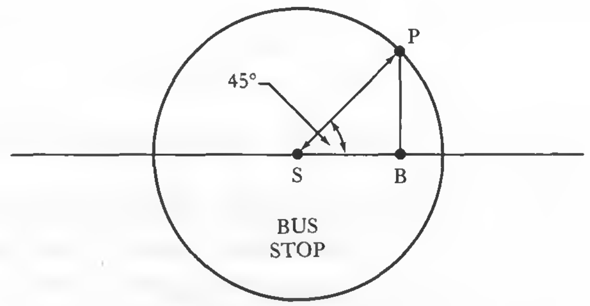
Figure 5. Walk time as a percent of total access time versus wait time as a percent of total access time

DETOUR FACTOR

The detour factor for a walking trip from a point in a catchment area to a bus stop is defined as the ratio of the actual walking distance to the airline distance, namely:

$$\text{detour factor} = \frac{\text{actual walking distance}}{\text{airline distance}} \tag{5}$$

Figure 6 depicts the maximum walking distance and detour factor for a circular and rectangular catchment area. As shown in Figure 6 the maximum walking distance is $\sqrt{2}\,d$ and d for a circular and rectangular area respectively. The maximum walking distances corre-

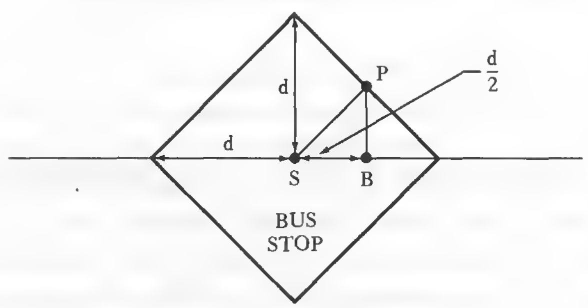


Circular Catchment Area of Radius d

Rectangular grid access detour factor $= \dfrac{PB + BS}{d}$

Maximum walking distance $= \sqrt{2}$ at 45°

Maximum detour factor $= \sqrt{2}$



Rectangular Catchment Area
With Diagonal 2d

Rectangular grid access detour factor $= \dfrac{PB + BS}{PS}$

Maximum walking distance $=$ d

Maximum detour factor $= \sqrt{2}$

Figure 6. Catchment area and detour factor

TABLE VII—DETOUR FACTORS FOR SELECTED AREAS

Service Area	*Route Type*	*Headways (seconds)*	*Detour Factor* *Summer*	*Detour Factor* *Winter*
Suburban Residential	Express & Regular	300–480	1.24	1.26
Central Business District	Express & Regular	300–480	1.15	1.29
Industrial Area	Industrial Feeder	1,800	1.06	1.20
City-Wide	All Routes Combined	—	1.18	1.24

spond to detour factors of $\sqrt{2}$ in both cases. In actual fact, however, bus stops are connected to residential areas and other land-uses by various street patterns such as grid or radial, back lanes, and sidewalks resulting in detour factors that are site specific. The detour factors for selected areas in Calgary are shown in Table VII. In general the longest detour factors were found in residential areas and the shortest in the industrial areas. This difference can be explained by the fact that pedestrian trips in residential areas are confined to streets, sidewalks, and back lanes, while pedestrian trips in industrial areas are made directly across parking lots and fields. The detour factors for winter were found to be greater than the summer factors in all areas. Longer winter time detour factors are the result of pedestrians having to circumnavigate snow covered fields and slippery back lanes. The city-wide detour factors of 1.18 for summer and 1.24 for winter compare with the 1.22 to 1.37 for Bremen and 1.24 for Zurich reported by Bandi *et al.*[5] Detour factors for Calgary were also found to reported by Bandi for European data.

CONCLUSIONS

The main conclusions of the Calgary study were as follows:

1. Measurement of bus passenger walking distances by means of tracing the exact path taken on large scale base maps, with the assistance of field surveyors, proved to be a fast and accurate method of determining walking distance distributions.

2. Mean walking distances were found to be 322 and 329 meters (1,056 and 1,079 feet) for summer and winter conditions respectively. The 75th percentile was found to be 450 meters (1,476 feet).

3. Waiting times in winter are less than those for summer for all ranges of headways. For headways under 600 seconds the average

5. F. Bandi, P. Brouwer, M. Cabeza, J. Nyst, and F. Lehner, "Length of Walking Distance and Distance Between Stops", *UITP Revue* 3/1974.

waiting time is approximately one-half the headway. Beyond this point the use of this approximation will overstate average waiting time, that tended to be 11 minutes for longer headways. Thus, the assumption made in some transportation studies that the average passenger waiting time is equal to one-half the headway is incorrect for large headways. Tests on the Calgary data showed that the assumption of random passenger arrivals is not valid.

4. Detour factors were found to be greatest in suburban residential areas and smallest in industrial areas. On a city-wide basis detour factors were 1.18 and 1.24 for summer and winter respectively. The detour factor decreases with increasing distance from the bus stop.

5. For most bus passengers walking time exceeds waiting time. On a city-wide basis bus passengers were found to have an access component ratio of 55 percent walk and 45 percent wait in summer, and 65 percent walk and 35 percent wait in winter.

RECOMMENDATIONS

The most surprising finding of this study was the fact that so little research has been undertaken on the effect that inclement weather has on urban transportation planning criteria and in particular the effect on walking and waiting times for public transport. With most of Canada and northern United States subjected to inclement weather for up to 6 to 8 months per annum any research undertaken on this particular topic or other critical areas such as the effect on roadway capacity, would be welcomed. A direct recommendation resulting from the findings of this study is that more research is required to measure the influence that different modes of public transit, such as commuter rail, metro, and light rail, have on walking and waiting times in summer and winter. The effect that light rail has on transit catchment areas could be part of the overall impact study proposed for the new Calgary Light Rail Transit System. The findings of this study also suggest that the transit catchment area needs careful redefinition. With the 75th percentile walking distance at 450 meters (1,476 feet) the zone of influence of a transit stop excludes a substantial portion of residential neighborhoods presently considered to be covered by existing transit service in Canadian cities. In addition, catchment area boundaries should be drawn taking into account the detour factor. This study, similar to most previous studies on the topic, concentrated on the residential end of the transit trip. Little is known about walking and waiting times at the destination end of transit trips in non-

residential areas. Observations made during the course of this study clearly indicated the need for more conveniently located stops, particularly in industrial areas and at shopping centers. In recommending that more summer/winter transit passenger walking and waiting data needs to be collected in other cities, a special plea is made for data collection at the destination end of the trip. The land-use planning implications of this project suggest that residential dwellings, especially high density housing, in new areas should be clustered as to lie within the catchment boundaries of a transit stop, if in fact transit is to be a viable component of new suburban development. In addition, residential neighborhoods should be planned, in terms of street and sidewalk network pattern as to reduce the detour factor. Existing planning criteria regarding transit stop locations, particularly in industrial areas and at shopping centers should be reviewed in light of the evidence that existing stop locations are typically remote from building entrances, thus placing the transit passenger at a severe disadvantage as compared to the auto user. Clearly, if transit is to become a viable alternative to the automobile in our larger urban centers, more understanding of the single most important component of the transit trip, namely, access and egress walking and waiting times is required.

Acknowledgement

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